PATENT SPECIFICATION

DRAWINGS ATTACHED

Inventors: EDWARD MICHAEL BRADLEY and WALTER SCOTT CARTER

1,004,739

1,004,739

THE PATENT OFFICE LONDON

Date of filing Complete Specification May 17, 1963.
Application Date May 30, 1962. *No. 20800/62.*
Complete Specification Published Sept. 15, 1965.

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Index at acceptance: —C7 F(1V1, 2P, 2T, 3C, 3E, 4W, 4X)
Int. Cl.: —C 23 c

COMPLETE SPECIFICATION

Improvements in or relating to Vacuum Deposition Apparatus

We, INTERNATIONAL COMPUTERS AND TABULATORS LIMITED a British Company of I.C.T. House, Putney, London, S.W.15, formerly of 17, Park Lane, London, W.1., do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement: —

The present invention relates to improved vacuum deposition apparatus for the formation of thin films on supporting substrates by an evaporation-deposition process in vacuo, the substrates being heated during the period of deposition.

The vacuum deposition of thin magnetic films and dielectric films on supporting substrates is described, for example, in a paper entitled "Preparation of Thin Magnetic Films and Their Properties" by M. S. Blois, published in the Journal of Applied Physics, Volume 26, Number 8 August, 1955.

It has been found in forming a thin film on a substrate by this process, to maintain the supporting substrate at an elevated temperature during the deposition of the film. Previously proposed substrate heating arrangements have included a sole plate upon which the substrate is supported. The sole plate has then been heated by an electric heating element insulated from the sole plate by mica spacers. These mica spacers have tended to cause contamination of the film by 'outgassing" at high temperatures. Furthermore, due to the high thermal capacity of the sole plate made necessary by the requirements of constant temperature of the entire substrate during the deposition process, it has been found that the time taken for the sole plate to cool to room temperature in vacuo is excessively long.

It is an object of the present invention to provide improved vacuum deposition apparatus in which the above-mentioned disadvantages of the previously proposed substrate heating arrangements are at least partly overcome.

According to the present invention, vacuum deposition apparatus includes a substrate support plate, a fluid-conduction path arranged in thermally-conductive relationship with the support plate, means to cause heating of the support plate during a heating period, and means operable during a cooling period to pass a cool fluid through the fluid-conduction path to cause cooling of the support plate.

The means to cause heating of the support plate may be an electric element arranged to heat the support plate by conduction. This element may be attached, for example by brazing, on to one surface of the support plate, or it may be clamped to the support plate by a further plate.

Alternatively, the means to cause heating of the support plate may comprise means to pass a hot fluid through the fluid-conduction path.

The fluid-conduction path is preferably a tube of thermally conductive material brazed on to one surface of the support plate, or, in the case where there is provided a heating element clamped to the support plate by a further plate, the tube may be brazed on to a surface of the further plate.

The cool fluid may be an inert gas (as hereinafter defined), for example nitrogen, or it may be a liquid, for example a silicone oil. Similarly, the hot fluid may be either such a gas or liquid.

Examples of vacuum deposition apparatus according to the present invention will now be described with reference to the accompanying drawings, in which: —

Figure 1 shows, diagrammatically, a pictorial view of the apparatus, including one form of substrate heating and cooling arrangement,

Figure 2 shows, diagrammatically, a pictorial view of an alternative form of substrate heating and cooling arrangement, and Figure 3 shows, diagrammatically, a view, partly in cross-section, of a further form of substrate heating and cooling arrangement.

Referring to Figure 1 of the drawings, vacuum deposition apparatus 1 includes a bell-jar 2 and a base 3 on to which the bell-jar 2 is sealed. A flat thermally-conductive sole plate 4 is supported within the bell-jar 2, and a substrate 5, on which a film is to be deposited, is mounted on that surface 6 of the plate 4 which is nearer the base 3. The substrate 5 may be mounted on the plate 4 by any suitable means, for example by clips (not shown). A crucible 7, positioned between the substrate 5 and the base 3, holds material which is to be evaporated by heating (in known manner) to cause deposition of a film on the exposed surface 11 of the substrate 5. A vacuum pump 8 is connected by a pipe 9 to a port 10 in the base 3 for evacuation of the bell-jar 2. It will be appreciated that the apparatus 1 will normally include other devices, for example the means for heating the crucible 7, means for supporting the plate 4, vapour control shields, masks and gates, but these devices are all well known in the art, and since they are not necessary to illustrate the present invention, they have not been shown in the drawings and no further description of them will be given.

A copper tube 12 is bent in serpentine fashion to cover the surface 13 of the plate 4, opposite the surface 6, as evenly as practicable. The tube 12 is fixed in good thermal contact with the surface 13 by brazing. The ends 14 and 15, respectively, of the tube 12 are formed into expansion coils 16 and 17 and are led through the base 3 by way of vacuum seals 18 and 19, respectively. The end 14 of the tube 12 is vented to the atmosphere, and the end 15 is connected to a nitrogen cylinder 20 through a control valve 21.

A heating element 22 is formed by enclosing a resistance wire, surrounded by a suitable insulating material, within a copper tube of, for example, 1 m.m. diameter. This element 22 is attached to the surface 13 of the plate 4 by brazing, the element 22 being first bent into a serpentine shape so that it lies between the loops of the tube 12. Lead-out wires 23 are connected to the ends of the resistance wire of the element 22. In order to facilitate the vacuum sealing of the element 22, the lead-out wires 23 are threaded through copper tubes 24 which are brazed on to the ends of the copper tubes of the element 22. These tubes 24 pass through vacuum seals 25 in the base 3, and the lead-out wires 23 are connected to an electrical power supply 26, one lead-out wire 23 having a switch 27 connected therein to control the flow of current through the element 22.

In operation of the substrate heating and cooling arrangement, the substrate 5 is heated for the deposition process by passing current through the element 22 from the supply 26. In order to cool the substrate 5 after the deposition period is finished, the switch 27 is opened to arrest the current flow and the valve 21 is opened to pass cool nitrogen through the tube 12.

It has been found that, whereas a plate 4 of a given size requires approximately two hours to cool unaided from 300°C to room temperature in a vacuum, this cooling period is reduced to about ten minutes by the passage of the cool nitrogen through the tube 12. Thus, the period of waiting between the deposition of successive films is considerably reduced and the productivity of the apparatus is thereby increased. Furthermore, since the insulating material of the heating element 22 is sealed within a copper tube, there can be no contamination of the film due to "outgassing" of this material.

In a second example, shown in Figure 2 of the drawings, only an alternative form of the substrate heating and cooling arrangement is illustrated, but it will be understood that the arrangement of the bell-jar 2, the base 3, the crucible 7 and the evacuating system may be exactly as shown in Figure 1. Features shown in Figure 2 which correspond with features shown in Figure 1 have been given corresponding reference numerals.

Referring to Figure 2, the heating element 22 is, in this case, not brazed on to the plate 4 but is positioned between two copper plates 28 and 29, and the assembly of the element 22 and the plates 28 and 29 is clamped to the sole plate 4 by a plurality of screws 30 (only two of which are shown) screwed into threaded holes in the plate 4. Thus, one surface of the plate 28 is in good thermal contact with the plate 4. For clarity, the loops of the element 22 are shown at right angles to the loops of the tube 12, but this is by no means essential. In this modification, the tube 12 is brazed on to the outer surface of the plate 29. If desired, the plate 28 may be omitted, the element 22 then being in direct contact with the plate 4.

The operation of this arrangement is identical with that of the arrangement shown in Figure 1, but the securing of the element 22 to the plate 4 by clamping, instead of by brazing, facilitates any replacement of the element 22 which may be necessary.

Another alternative arrangement for heating and cooling the substrate is shown in Figure 3 of the drawings, in which features which correspond with features shown in Figures 1 and 2 have been given corresponding reference numerals.

Referring to Figure 3, the means for heating the plate 4 is, in this case, not provided by a heating element as in the previous examples, but is provided solely by the tube 12 which, as in Figure 1, is brazed on to the surface 13 of the plate 4. The end 15 of the tube 12 is not, however, connected directly to the valve 21 of the cylinder 20, but is connected to a heat exchanger 31. This heat exchanger 31 comprises a hollow cylinder 32 having one end 33 closed and having a flange 34 on the opposite end 35. An end cap 36, secured to the flange 34 by means of bolts 37 and nuts 38, closes the end 35 of the cylinder 32, a small central aperture 39 being provided through the cap 36. The extreme tip of the end 15 of the tube 12 is brazed into the cap 36, so that the said tip is aligned with the aperture 39. One end of tube 40 is brazed into the end 33 in alignment with an aperture 41 which extends through the end 33. To the opposite end of the tube 40, the valve 21 of the cylinder 20 is connected. A baffle 42 is fitted, within the cylinder 32, opposite each of the apertures 39 and 41.

An electrically insulated former 43, having a helical heating element 44 supported thereon, is positioned within the cylinder 32. The ends 45 of the element 44 are attached to terminals 46 which project through, and are electrically insulated from, the cap 36. The terminals 46 are connected by wires 47 to an electrical power supply 48, a switch 49 being included in one of the wires 47 to control the supply of current to the heating element 44.

In operation of this arrangement, nitrogen is passed from the cylinder 20 into the cylinder 32 of the heat exchanger 31 under the control of the valve 21. The heating element 44 is energised and the nitrogen, heated by passing over the element 44, is fed through the tube 12, thus heating the plate 4 and the substrate 5. The nitrogen then escapes into the atmosphere from the end 14 of the tube 12. The temperature of the substrate 5 is controlled by adjustment of the rate of flow of nitrogen through the heat exchanger 31 and also by the temperature of the heating element 44. The rate of flow of nitrogen is controlled by the valve 21, and the temperature of the element 44 by the magnitude of the current passed therethrough by the supply 48. The supply 48 may, therefore, include a variable output transformer to provide this control of the current.

The plate 4 must be maintained at a temperature of, for example, 300°C. Since the tube 12 is in intimate thermal contact with the plate 4, the temperature of the tube 12 need not be greatly in excess of 300°C. This arrangement is, therefore, superior to the known forms of electrical heating of substrates in which a heating element is insulated from the sole plate by mica spacers, the heating element then being necessarily at a much higher temperature of, say, 700°C.

Cooling of the substrate 5 is, in this embodiment, obtained by switching off the supply to the heating element 44 to allow cool nitrogen to flow through the tube 12.

It will be appreciated that various modifications of the above examples may be made without departing from the ambit of the invention. Thus, other suitable cooling and heating fluids may be used in place of nitrogen. For example, other "inert" gases could be used, the term "inert" being used in this specification to describe gases which are non-inflammable and which have no appreciable chemical affect on the parts of the apparatus with which they make contact. Alternatively, the cylinder 20 could contain a liquid such as a silicone oil. In the arrangement described with reference to Figure 3, the nitrogen flows directly over the the heating element 44. Where some types of fluids are used, it may be necessary to form the element 44 by enclosing an insulated resistance wire inside a copper tube so that the fluid does not come into direct contact with the resistance wire. Since the thermal capacity of the element 44 may then be high, it may be convenient to leave the element 44 energised during the deposition of a succession of films. Arrangements would then be made to provide a further tube to by-pass the heat exchanger 31, so that the fluid flows through the heat exchanger 31 when heating of the substrate 5 is required, but flows directly from the cylinder 20 into the tube 12 during cooling.

Although, in the foregoing description, it has been proposed that the tube 12 is made of copper and is brazed on to the plate 4 or the plate 29, it will be clear that the tube may be of any other suitable thermally-conductive material, and that the tube 12 may be attached to the plate 4 or the plate 29 by any means which will provide good thermal contact between the tube 12 and the respective plate 4 or 29. Furthermore, the tube 12 may be replaced by any other suitable fluid-conduction path which is in good thermal contact with the plate 4. For example, a serpentine channel may be formed within the plate 4 by a milling operation, a fluid-tight cover then being fitted over the channel.

Instead of the fluid being passed from the cylinder 20 into the tube 12 from which it is allowed to escape into the atmosphere, it would be possible to provide a recirculatory system in which the fluid is fed into the tube 12 by a pump and is then returned to the pump after passing round the loops of the tube 12. In this way the fluid would not be wasted, but it would then be necessary to provide means, operative during the cooling period, to cool the fluid before returning it to the pump. Such means could, for example, comprise a coil of finned piping or a refrigerating coil through which the fluid is passed.

The foregoing description has assumed that the deposition apparatus is to be employed for the production of thin ferro-magnetic film devices. It will be understood, however, that the apparatus provided by the present invention is suitable for use in the vacuum deposition of film materials for the production of other devices such as, for example, cryogenic devices.

WHAT WE CLAIM IS: —

1. Vacuum deposition apparatus, including a substrate support plate, a fluid-conduction path arranged in thermally-conductive relationship with the support plate, means to cause heating of the support plate during a heating period, and means operable during a cooling period to pass a cool fluid through the fluid-conduction path to cause cooling of the support plate.

2. Apparatus according to Claim 1, in which the means to cause heating of the support plate is an electric element arranged to heat the support plate by conduction.

3. Apparatus according to Claim 1, in which the means to cause heating of the support plate comprises means to pass a hot fluid through the fluid-conduction path.

4. Apparatus according to Claim 2, in which the electric element is brazed on to one surface of the support plate.

5. Apparatus according to Claim 2, in which the electric element is clamped to the support plate by a further plate.

6. Apparatus according to any one of Claims 1, 2, 3 or 4, in which the fluid-conduction path comprises a tube of thermally-conductive material brazed on to one surface of the support plate.

7. Apparatus according to Claim 5, in which the fluid-conduction path comprises a tube of thermally-conductive material brazed on to a surface of said further plate.

8. Apparatus according to any preceding claim, in which the cold fluid is an inert gas (as hereinbefore defined).

9. Apparatus according to Claim 3, in which the hot fluid is an inert gas (as hereinbefore defined).

10. Apparatus according to Claim 8 or Claim 9, in which the gas is nitrogen.

11. Apparatus according to any of Claims 1—7, in which the cold fluid is a liquid.

12. Apparatus according to Claim 3, in which the hot fluid is a liquid.

13. Apparatus according to Claim 11 or Claim 12, in which the liquid is a silicone oil.

14. Vacuum deposition apparatus constructed and arranged to operate substantially as hereinbefore described with reference to Figure 1 of the accompanying drawings.

15. Vacuum deposition apparatus constructed and arranged to operate substantially as hereinbefore described with reference to Figure 1, and modified as described with reference to Figure 2 of the accompanying drawings.

16. Vacuum deposition apparatus constructed and arranged to operate substantially as hereinbefore described with reference to Figure 3 of the accompanying drawings.

R. V. P. LOUGHREY,
Chartered Patent Agent,
Agent for the Applicants.

Leamington Spa: Printed for Her Majesty's Stationery Office by the Courier Press.—1965.
Published at The Patent Office, 25, Southampton Buildings, London, W.C.2, from which copies may be obtained.

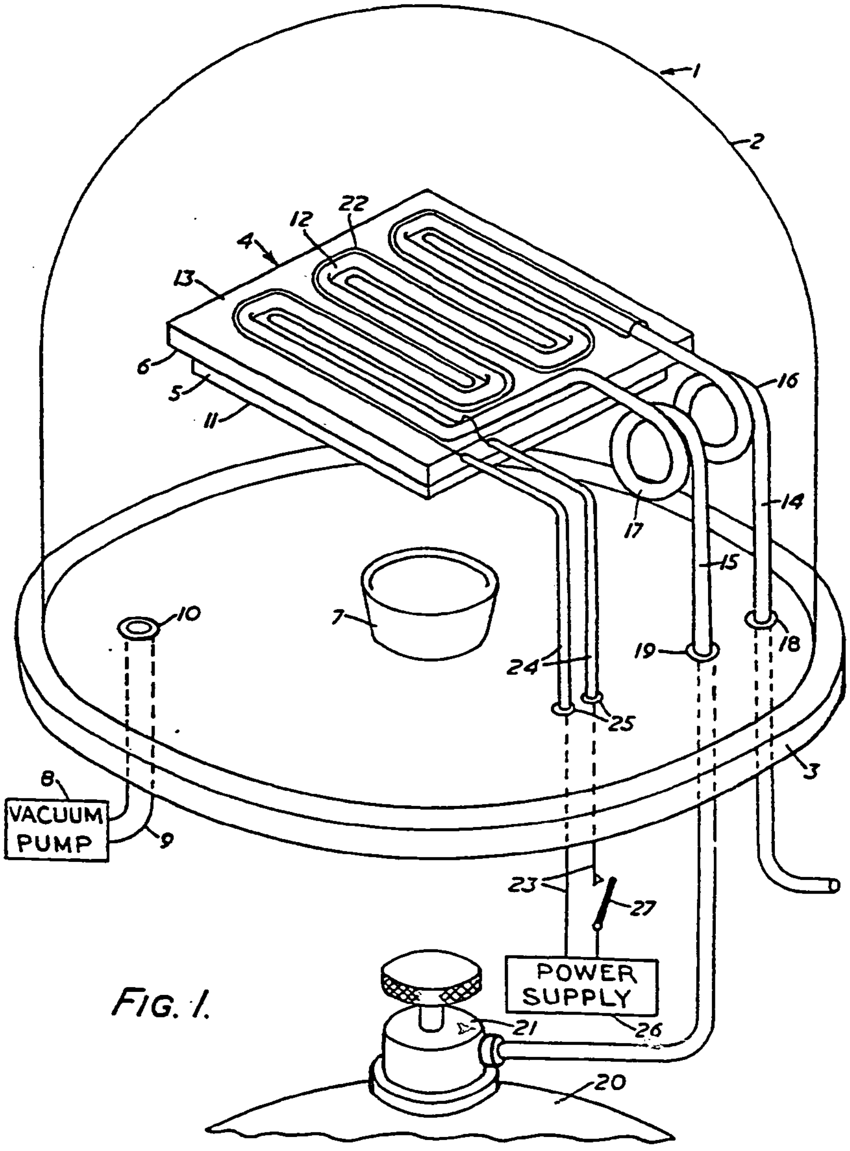
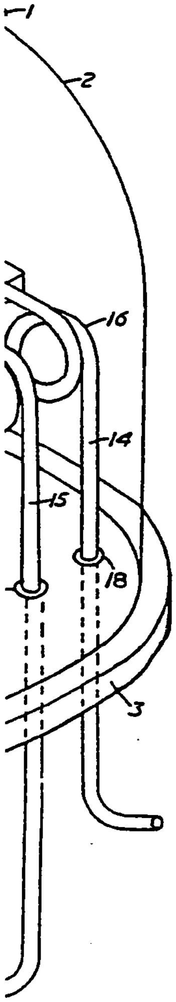

VACUUM PUMP
POWER SUPPLY

FIG. 1.

1004739 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheets 1 & 2



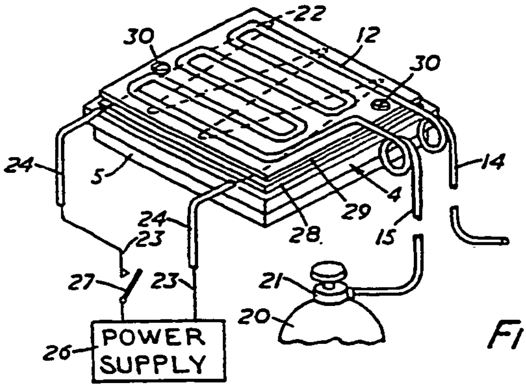


FIG. 2.

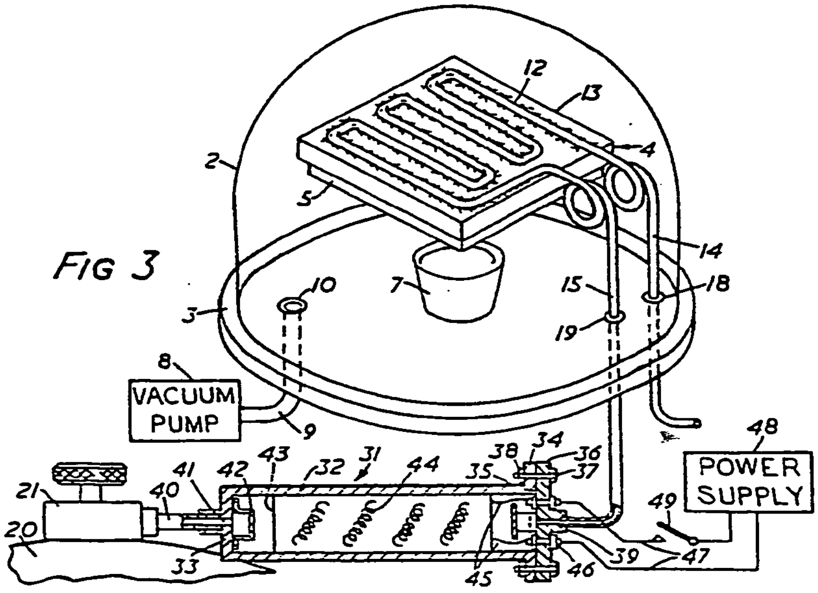


FIG 3

1004739 COMPLETE SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheets 1 & 2

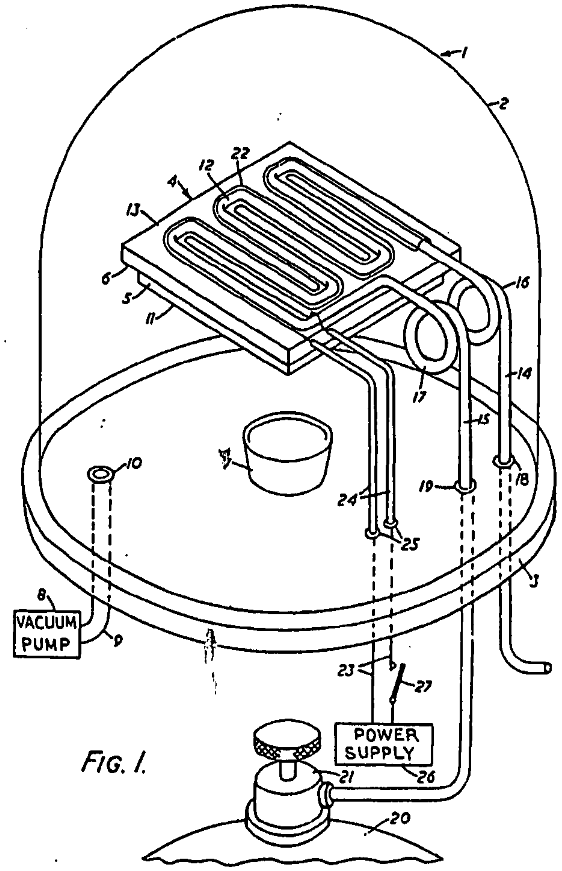


FIG. 1.

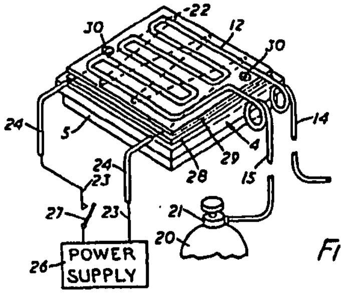


FIG. 2.

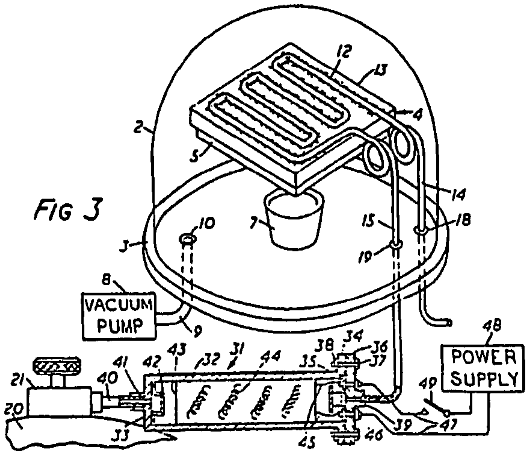


FIG 3